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Bud break and spring frost hardiness in *Picea abies* seedlings in response to photoperiod and temperature treatments

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Abstract: Spring frost may result in detrimental damage in newly planted *Picea abies* (L.) Karst. seedlings if their growth rhythm is not sufficiently adapted to the climatic conditions on the forest site. The aims of this study were to evaluate how bud break and spring frost hardiness were influenced by short-day (SD) treatments with different timing and different temperature regimes during bud formation. Following winter storage, frost hardiness was tested after 1, 3 and 5 weeks in forcing conditions. The SD treatment advanced bud break compared with the control seedlings. In comparison, the effects of timing and the different temperatures on bud break were small. The SD treatment improved frost hardiness in first-year needles during dehardening. The early SD treatment resulted in improved frost hardiness in first-year needles and greater root collar diameter compared with later SD treatment. To avoid a second bud flush, it is important that a critical night length is attained when the SD treatment terminates. Low temperatures following the SD treatment resulted in increased hardiness of the needles and decreased hardiness of the stems. The contrasting effect of temperature in different plant tissues demonstrates the importance of examining different tissues following freezing tests.

Résumé : Le gel printanier peut être dommageable pour les semis de *Picea abies* (L.) Karst. nouvellement plantés si leur rythme de croissance n'est pas suffisamment adapté aux conditions climatiques de la station forestière. Les objectifs de cette étude consistaient à déterminer de quelle façon le débourrement et la résistance au gel printanier sont influencés par un traitement de jours courts (JC) appliqués à différents moments et avec différents régimes de température durant la période de formation des bourgeons. À la suite d'un entreposage hivernal, la résistance au gel a été évaluée après une, trois et cinq semaines dans des conditions de forçage. Le traitement JC a avancé le débourrement comparativement aux semis témoins. Par comparaison, le moment du traitement et les différentes températures ont eu peu d'effet sur le débourrement. Le traitement JC a augmenté la résistance au gel des aiguilles d'un an pendant la période de désendurcissement. Appliqué tôt, le traitement JC a augmenté la résistance au gel des aiguilles d'un an et le diamètre au collet comparativement à une application plus tardive. Il est important que la période de noirceur atteigne une durée critique lorsque le traitement JC prend fin pour éviter une deuxième éclosion des bourgeons. Des températures basses à la suite du traitement JC ont augmenté la résistance au gel des aiguilles et diminué celle de la tige. Les effets contraires de la température sur différents tissus végétaux démontrent l'importance d'examiner différents tissus après des essais de gel-dégel.

[Traduit par la Rédaction]

Introduction

A growth rhythm adapted to the climatic conditions on the forest site is crucial for the survival of newly planted *Picea abies* (L.) Karst. seedlings. Late spring frost that coincides with the sensitive phase of bud break and shoot elongation is of particular concern (Sakai and Larcher 1987). The timing of bud break in *P. abies* is mainly a response to chilling and accumulation of thermal time, and there is a marked loss of hardiness in the seedlings prior to bud break (Wareing 1956; Repo 1992; Hannerz 1999). When frost occurs at early bud break stages (swollen bud), seedlings may avoid severe damage if the frost episode does not last too long. However, frost damage caused by temperatures in the range –15 to –20 °C has been reported in newly planted *P. abies* seedlings in southern Norway (Kohmann 1991). At the more advanced stages of bud break (shoot elongation 1–5 cm), the seedlings become increasingly susceptible (Dormling et al. 1968), and the exposure time has less influence on the risk of damage compared with the effect of temperature per se (Bigras et al. 2004). Radiation frost may then lead to critical subzero temperatures (Langvall et al. 2001), which poses a substantial threat to successful reforestation in southern Scandinavia.

Even when comparing *Picea* seedlings at the same stage of shoot elongation, frost hardiness can differ depending on the provenance and hardening regime the previous autumn (Dormling 1982; Hannerz 1994; Coursolle et al. 1997). Although the differences in frost hardiness at this time are small, they may still be important because minimum temperatures during frost events in late spring and early summer

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